EPA/540/R-03/500
March 2004

MINERGY CORPORATION
GLASS FURNACE TECHNOLOGY EVALUATION

INNOVATIVE TECHNOLOGY EVALUATION REPORT

National Risk Management Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

NOTICE

The information in this document has been funded by the U.S. Environmental Protection Agency (EPA) under Contract No. 68-C0-00-181 to Tetra Tech EM Inc. It has been subjected to EPA peer and administrative reviews and has been approved for publication as an EPA document. Mention of trade names or commercial products does not constitute an endorsement or recommendation for use.

FOREWORD

The U.S. Environmental Protection Agency (EPA) is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, EPA strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to nurture life. To meet this mandate, EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

The National Risk Management Research Laboratory (Laboratory) is the Agency's center for investigation of technological and management approaches for reducing risks from threats to human health and the environment. The focus of the Laboratory's research program is on methods for prevention and control of pollution to air, land, water, and subsurface resources; protection of water quality in public water systems; remediation of contaminated sites and groundwater; and prevention and control of indoor air pollution. The goal of this research effort is to catalyze development and implementation of innovative, cost-effective environmental technologies; develop scientific and engineering information needed by EPA to support regulatory and policy decisions; and provide technical support and information transfer to ensure effective implementation of environmental regulations and strategies.

This publication has been produced as part of the Laboratory's strategic long-term research plan. It is published and made available by EPA's Office of Research and Development to assist the user community and to link researchers with their clients.

Lee Mulkey, Acting, Director
National Risk Management Research Laboratory

ABSTRACT

This report presents performance and economic data for a U.S. Environmental Protection Agency (EPA) Superfund Innovative Technology Evaluation (SITE) Program demonstration of the Minergy Corporation (Minergy) Glass Furnace Technology (GFT). The demonstration evaluated the technology's ability to reduce polychlorinated biphenyl (PCB) and metal concentrations in river sediment.

GFT was developed by Minergy to remove PCBs, other organics, and metals from river sediment. The GFT consists of a dryer, a melter, and an air pollution control system. After drying to about 10percent moisture, the dried sediment is mixed with a flux material to control melting temperatures and improve the physical properties of the glass aggregate product, and introduced into the melter. The sediment is heated in the melter to a temperature of about 1,600 degrees Celsius (°C), at which temperature the sediment is molten. At these high temperatures, PCBs and organic contaminants are destroyed or removed, and metals are encapsulated within the glass matrix. The molten sediment exits the melter into a water-quench bath, where it quickly hardens and shatters to form glass aggregate that, Minergy maintains, has reuse value.

Laboratory tests of sediment samples collected during a pilot dredging project on the Lower Fox River, Wisconsin, indicated that the sediment was suitable for melting using the GFT. A demonstration of an indirect-disk or paddle dryer, the intended type of dryer for a full-scale implementation of the GFT, was conducted by Hazen Research, Inc., at its facility in Golden, Colorado in January 2001. A pilot-scale melter was designed and built at Minergy's facility in Winneconne, Wisconsin, where the GFT demonstration treated a total of about 27,000 pounds of dried sediment in the Summer of 2001.

The primary objective for the GFT technology demonstration was to evaluate the treatment efficiency of PCB destruction or removal by the GFT process during the demonstration period. Results of the demonstration indicate that Minergy's GFT removed 99.9995 percent of the PCB contamination in the sediment.

This technology is potentially applicable at hazardous waste sites where river sediment has been impacted by PCBs, other organics, and metals. Economic data indicate that remediation costs of using GFT are affected by site-specific factors, such as local land prices and site suitability. The cost for treatment using a full-scale treatment facility, constructed at a location in proximity to sediment removal activities, was calculated to be $38.74 per ton of dredged-and-dewatered sediment (containing about 50 percent moisture). Treatment costs, which are affected by the amount of moisture in the sediment and potential end use of the glass aggregate, are based on operating a melter on an average of 600 tons of sediment per day over a 15-year project life.

CONTENTS

Section **Page**

FIGURES

TABLES

ACRONYMS, ABBREVIATIONS, AND SYMBOLS

ARARs	Applicable or relevant and appropriate requirements
ASTM	American Society for Testing and Materials
ATSDR	Agency for Toxic Substances and Disease Registry
CAA	Clean Air Act
CAMU	Corrective action management unit
°C	Degrees Celsius
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
COC	Contaminant of concern
Comp	Composite
DOT	Department of Transportation
dryer	Indirect heat disk or paddle dryer (can we delete this one?)
EPA	U.S. Environmental Protection Agency
°F	Degrees Fahrenheit
FS	Feasibility study
GFT	Glass Furnace Technology
GLNPO	Great Lakes National Program Office
Hazen	Hazen Research, Inc.
HSWA	Hazardous and Solid Waste Amendments
ID	Identification
ITER	Innovative Technology Evaluation Report
J	Estimated
kg/hr	Kilogram per hour
kj	Kilojoule
kWh	Kilowatt-hour
Laboratory	National Risk Management Research Laboratory
LCS	Laboratory control sample
LCSD	Laboratory control sample duplicate
LDR	Land Disposal Restriction

ACRONYMS, ABBREVIATIONS, AND SYMBOLS (Continued)

M	Million
melter	Minergy's pilot-scale melter
Minergy	Minergy Corporation
mg	Milligram
mg/kg	Milligram per kilogram
mg/L	Milligram per liter
MS	Matrix spike
MSD	Matrix spike duplicate
NAAQS	National Ambient Air Quality Standards
NCP	National Contingency Plan
ND	Nondetect
NPV	Net present value
O_2	Oxygen
OMB	Office of Management and Budget
ORD	EPA Office of Research and Development
OSHA	Occupational Safety and Health Act
OSWER	Office of Solid Waste and Emergency Response
oxy-fuel	Oxygen and natural gas mixture
P	Primary
Paradigm	Paradigm Analytical Laboratories
PCB	Polychlorinated biphenyl
PCDD	Polychlorinated dibenzodioxin
PCDF	Polychlorinated dibenzofuran
%R	Percent recovery
PPE	Personal protective equipment
ppm	Parts per million
ppt	Parts per trillion
PW	Present worth

ACRONYMS, ABBREVIATIONS, AND SYMBOLS (Continued)

QA	Quality assurance
QAPP	Quality Assurance Project Plan
QC	Quality control
RCRA	Resource, Conservation, and Recovery Act
S	Secondary
SARA	Superfund Amendments and Reauthorization Act
SITE	Superfund Innovative Technology Evaluation
SMU	Sediment management unit
SPLP	Synthetic Precipitate Leaching Procedure
SVOC	Semivolatile organic compound
Tetra Tech	Tetra Tech EM Inc.
TE	Treatment efficiency
TEQ	Toxicity equivalent
TER	Technology Evaluation Report
tons/day	Tons per day
TSCA	Toxic Substances Control Act
TSD	Treatment, storage, and disposal
TSS	Total suspended solids
UCL_{95}	95 Percent upper confidence limit
VOC	Volatile organic compound
WAC	Wisconsin Administrative Code
WDNR	Wisconsin Department of Natural Resources

ACKNOWLEDGMENTS

This report was prepared under the direction of Marta K. Richards, the U.S. Environmental Protection Agency (EPA) Work Assignment Manager for this Superfund Innovative Technology Evaluation (SITE) Program demonstration at the National Risk Management Research Laboratory in Cincinnati, Ohio. The Glass Furnace Technology evaluation was a cooperative effort funded by Minergy Corporation (Minergy), Wisconsin Department of Natural Resources (WDNR), and EPA's Great Lakes National Program Office (GLNPO) and involved the following personnel from EPA, WDNR. Minergy, and Tetra Tech EM Inc. (Tetra Tech):

Marta K. Richards	EPA
Ann Vega	EPA
Scott Cieniawski	EPA - GLNPO
Mark Tuchman	EPA - GLNPO
Jeff Krieder	WDNR
Terry Carroll	Minergy
Tom Baudhuin	Minergy
Joe Dauchy	Tetra Tech
Ken Partymiller	Tetra Tech
Ken Brown	Tetra Tech

EXECUTIVE SUMMARY

The Glass Furnace Technology (GFT) treatment process was developed by Minergy Corporation (Minergy) as an *ex situ* remediation technology to treat river sediment contaminated with polychlorinated biphenyls (PCBs), other organic compounds, and metals. An evaluation of the technology was conducted by the U.S. Environmental Protection Agency (EPA) Superfund Innovative Technology Evaluation (SITE) Program. The demonstration of the GFT, which consisted of a drying process and a melting process, was completed at the Hazen Research, Inc. (Hazen) facility in Golden, Colorado, and Minergy's GlassPack Test Center facility in Winneconne, Wisconsin.

According to the vendor, Minergy, the GFT process was designed to treat contaminated river sediment and is intended for use at any location where dredging and remediation of sediment is prescribed. Although site-specific background data are not relevant to the SITE demonstration, the technology evaluation was conducted on river sediment dredged from the Lower Fox River in Green Bay, Wisconsin.

The purpose of this Innovative Technology Evaluation Report is to present information that will assist Superfund decision-makers in evaluating the GFT for application to hazardous waste site cleanups associated with contaminated river sediment. This executive summary describes the GFT, provides an overview of the SITE evaluation of the technology, discusses evaluation criteria for the GFT, and summarizes SITE evaluation results.

Glass Furnace Technology

The GFT process was developed and configured for this SITE demonstration by Minergy. The demonstration process consisted of two basic steps: sediment drying and dried-sediment vitrification. According to the vendor, a full-scale GFT project will integrate drying and melting operations in a single facility. Both processes were evaluated independently for the SITE demonstration. The dryer evaluation was conducted in Golden, Colorado in January 2001, and the melter evaluation was completed in Winneconne, Wisconsin in August 2001.

The GFT process was designed as an alternative treatment to landfilling for river sediment impacted by PCBs, other organics, and metals. Dewatered sediment is dried, flux is added to control melting temperatures and improve the physical properties of the glass aggregate product, and then the sediment and flux mixture melted at a temperature of about 1,600 degrees Celsius (°C) (2,900 degrees Fahrenheit [°F]), removing or destroying PCBs and organic contaminants, and encapsulating metals. The treated

product consists of black glass aggregate with particles the size of coarse sand. Minergy claims the glass aggregate meets state regulatory criteria for beneficial reuse.

For clarification, this document refers to the indirect heat disc or paddle dryer as the **dryer** and the pilot-scale melter portion of the GFT as the **melter.**

Overview of the GFT Technology SITE Demonstration

River sediment from a pilot dredging project conducted on the Lower Fox River in Green Bay, Wisconsin, was used to demonstrate the GFT. Sediment was delivered to the dryer in dewatered form (45 to 55 percent solids by weight). The purpose of the dryer demonstration was to reduce moisture in the sediment from 50 percent to about 10 percent moisture.

According to Minergy , after researching available sediment drying technologies, it was determined that, because of its low volume of sweep air and low potential for generating dust, a indirect heat disc or paddle dryer unit was the most appropriate drying technology for the GFT treatment process. Because this type of large-scale dryers were not available for rent and the purchase of an appropriately sized unit was too costly for the demonstration, Minergy chose a bench-scale Holoflite® dryer, located at the Hazen facility in Golden, Colorado to be used to dry a small amount of the sediment under very similar conditions to those in a large-scale dryer unit. For the melter to operate at optimal efficiency, the dried sediment must contain no more than 10 percent moisture. Sediment entering and exiting the dryer, air emitted from the dryer, and condensed water from the dried sediment were sampled as part the SITE evaluation of the technology. Data from the dryer evaluation were inadequate to use in the overall technology evaluation because sediment dust was drawn into the dryer vent, the condensate collection vessel, and air sampling equipment, and the PCB congeners analyzed were not the same as those analyzed in the sediment.

The bulk of the sediment was dried in a drum oven at Minergy's facility in Winneconne, Wisconsin. To permit the calculation of the overall efficiency of the GFT, samples were collected from the sediment before and after drying in the drum oven. The melting phase of the process was evaluated using a pilot-scale melter (melter) specifically designed for this SITE evaluation. The sediment, flux, glass aggregate, and waste streams were analyzed for predetermined contaminants of concern (COCs) before and after processing through the glass furnace. COCs included PCBs; dioxins and furans; metals, including mercury; and semivolatile organic compounds. The melter evaluation began in June 2001, but was halted after three days when molten sediment corroded a hole in the refractory brick. The

demonstration was stopped before evaluation sampling was completed. Repairs were made to the melter, and the demonstration was rerun in August without incident.

The SITE demonstration for the GFT was designed with two primary and three secondary objectives to provide potential users of the technology with the information necessary to assess the applicability of the GFT for other similarly contaminated sites.

The primary objectives (P) of the technology demonstration were as follows:

P1 **Determine the treatment efficiency (TE) of PCBs in dredged-and-dewatered river sediment when processed in the Minergy GFT.**

P2 **Determine whether the GFT glass aggregate product meets the criteria for beneficial reuse under relevant federal and state regulations. The aggregate product will be judged to be beneficial with respect to each metal or PCB if the 95 percentile upper confidence limit (UCL_{95}) for the estimated mean (of each metal or PCB) is less than the federal or state regulatory requirements, as applicable.**

The secondary objectives (S) of the technology demonstration were as follows:

S1 **Determine the unit cost of operating the GFT on dredged-and-dewatered river sediment.**

S2 **Quantify the organic and inorganic contaminant losses resulting from the existing or alternative drying process used for the dredged-and-dewatered river sediment.**

S3 **Characterize organic and inorganic constituents in all GFT process input and output streams.**

SITE Demonstration Results

Key findings of the GFT are listed below:

- Analytical data indicate that the GFT was able to significantly reduce PCB contamination in all samples collected. Overall, the GFT successfully removed or destroyed 99.9995 percent of the PCBs in the river sediment, measured as total PCBs.

- The GFT appeared to be capable of decreasing mercury concentrations in the river sediment. Mercury was observed in sediment at a concentration slightly less than 1 part per million (ppm), and it was not detected in the glass aggregate analysis. If not removed by the furnace thermally, the mercury likely was inactivated within the glass matrix. Mercury did not leach from the glass aggregate, as evidenced by the results of the American Society of Testing and Materials (ASTM) and Synthetic Precipitate Leaching Procedure (SPLP) water leach tests.

- The GFT reduced the concentration of dioxins and furans in dried sediment. Total dioxin and furan concentrations in the glass aggregate ranged from 1.8×10^{-6} to 3.8×10^{-6} parts per million (ppm), a reduction *of greater than* 99.9995 percent.

- The GFT produced glass aggregate that met Wisconsin Administrative Code Chapter NR 538 Category 2 criteria and qualified for beneficial reuse under the regulation. This qualification allows a wide range of uses, including as an additive to concrete, a material in floor tiles, and as construction fill.

- Minergy demonstrated the dryer and melter technologies separately. Data collected during the Holoflite® dryer test were not used to determine the TE because of the sediment carry-over into all waste streams and the incompatibility of the PCB congener lists analyzed for the dryer and melter evaluations. The TE was calculated using data obtained from sampling dredged-and-dewatered sediment from roll-off boxes and dried sediment from the drum dryer.

- Samples of the glass aggregate were crushed and subjected to ASTM and SPLP leaching analyses. The results of the leaching tests indicated no detections of contaminants of concern in leachates for either method.

- The air sample probe and the flue of the pilot-scale furnace were occasionally clogged by dust during the furnace operation. Removal of the accumulated dust interrupted air sample collection frequently during the demonstration. Analysis of the dust material indicated the presence of metals such as lead and chromium. Dioxins and furans were detected in very small concentrations (1.0×10^{-5} ppm) in those dust samples.

- Post-carbon treatment air samples show a reduction in PCB congeners and PCDD/PCDF concentrations detected in the melter flue gas samples.

- Based on information from Minergy and observations made during the SITE evaluation, the estimated treatment cost is $38.74 per ton of dredged-and-dewatered sediment containing 50 percent moisture. Unit costs are based on a 15-year project life expectancy and may depend on the location of the treatment facility, amount of moisture in the sediment, and potential end use of the product.